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SOLAR DESIGN COURSE MANUAL

Part III: ADVANCED (Practical Considerations)

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Information and Assistance:

R. Culham
Technology Transfer Engineer
Solar Programs Office
Sir Charles Tupper Building
Confederation Heights
Ottawa K1A 0M2

(613) 998-3641

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APPENDIX A

1. EVALUATING OPPORTUNITIES FOR SOLAR ENERGY SYSTEMS

Much of the success of a solar heating system rests with the initial feasibility study. A number of items must be addressed during the feasibility study stage of a solar system project. These include answering the following questions:

- Is the load being considered a good application for a solar heating system?

- Can the solar heating system be easily and cost effectively integrated with existing energy systems?

- Is the required space available for the collector array, necessary heat exchangers, thermal storage and other system components?

- If the collector array is to be roof mounted, is the existing roof structure adequate to carry the collector array without significant modifications?

- Can piping be installed in such a way that required slopes are available, particularly in the case of drainback systems?

- After the system has been installed, will adequately qualified maintenance staff be available to operate and repair the system?

A NO answer to any of these questions may indicate that the load being assessed for application of a solar heating system is indeed not a good one.

1.A LOAD EVALUATION

Today, by far, the largest effort in the active solar heating area is in the production of domestic or process hot water. The systems range in size from extremely large engineered systems such as the Mohawk Hospital Services System constructed under the Ontario Demonstration Programme consisting of over two thousand square metres of collector area, to small package systems consisting of approximately four square metres of collector area.

One of the areas most often neglected, in the feasibility study phase of a solar project, is accurate assessment of the total load and particularly load profiles. Many systems have been carefully designed based on totally erroneous load profile estimates. Often, because details of load profiles were not necessary to the operation of the existing energy systems, the system owner or operator had very little knowledge of the details of these load profiles. Experience has shown, in a very expensive manner, that if good load profile data is not available it must be developed before a solar heating design is proceeded with.

It is also important to consider at this point whether the load profile in an existing plant can be modified to more closely match available solar energy without adversely affecting the plant's operation. These changes, if acceptable, must be determined at the outset and the appropriate solar system design consideration made.

Other changes anticipated in the plant's operation must also be assessed at the time of the feasibility study. As an example, addition of heat recovery equipment in an existing plant will seriously affect the operation of a solar heating system. In some cases it will preclude the use of solar heating and in others radically change the required design.

The following criteria should be used when evaluating a load:

- The load should be large

- The load should be continuous or peaking when solar energy is available

- The load should be centrally located

- The load should utilize low temperature energy

One must also consider how the load would be affected if energy conservation procedures were applied.

In order to match the solar system size to the load required, we should compare energy load requirements on a daily basis and on a seasonal basis. When matching load to the available solar energy certain parameters can be manipulated:

- Time at which the load is used

- Amount of collector area

- Use of storage

The time of day in which the load is to be used is one of the most important to manipulate. If such an opportunity is available it would possibly limit or eliminate storage and make the solar system much more cost effective.

F-Charts or Watsun programs can help decide whether extra energy is to be stored or not.

For space heating requirements, peak solar loads occur at night and solar radiation occurs during the day. In this case, thermal storage is definitely required.

Here are some constraints to system sizing, aside from the load:

- With retrofit systems mounting area available is often limited,

- Methods and costs of integrating with existing mechanical systems can limit both feasibility and sizing of systems.

1.B BUILDING INTERFACE

1.B.1 Required Space for Collector Arrays, Heat Exchangers, Storage, etc.

Solar collectors may be roof mounted, ground mounted or in some cases wall mounted. In all cases the basic criteria are the same.

- Adequate support must be available

- Shading must be minimal

- Protection from vandalism must be adequate

- Presence of potential dirt sources must be minimal

Structural considerations for roof mounted arrays will be dealt with in detail in the next section, however, even for ground mounted array foundations requirements must be carefully considered at the outset.

With ground mounted arrays potential frost heaving must be considered because of its effect on pipe slopes. Particularly for drainback type systems where pipe sloping is critical, minor frost heaving can have disasterous effects.

Shading from large structures, such as adjacent buildings or large trees, are easy to assess and very obvious, however, small items such as roof vents and chimneys can cause shading problems on one or two collectors and lead to system operational problems.

It is also important to consider future potential obstructions to sunlight such as new buildings where a site is evaluated.

Vandalism has seldom been a problem with solar collector arrays but situations can exist where significant damage can occur.

Vandalism problems can usually be minimized by some careful thought when locating the array.

- Don't place collectors in school yards or other locations where children play;

- In public areas, place collectors well back from the edge of roofs;

- Ensure that roof access is made difficult for the unauthorized;

Often overlooked, where solar systems are designed for industrial applications, are sources of dirt which can cover a collector array and significantly decrease its performance.

The most common sources of dirt are combustion vents, and industrial dryer vents.

Although most surface contamination on collector glazing will be washed off by rainfall, heavy buildups of soots or lints will not, and hence, collectors will required frequent and time consuming washing.

Whether a solar system be large or small, adequate space for the location of components is an absolute necessity. Numerous systems have been installed with little consideration for future maintenance of components.

Some examples of bad practices we have seen include systems where components were arranged so that a major effort is required to access items needing relatively frequent attention, such as pumps and heating coils. Package solar heating systems have been installed where it is necessary to remove most of the solar heating system to access the heating element in a domestic electric heating tank. Even when adequate space is available logical placement of components for ease of maintenance must be considered. As an example, in one system the fill valve, which requires relatively frequent attention, was installed at ceiling level.

Generally, choosing a location for the solar storage tank is one of the easier decisions. It is usually placed in the existing mechanical room near major services such as electricity, gas and, of course, water mains. Some rules of thumb do apply and should be adhered to when locating storage tanks:

1. Locate the storage tank as close as reasonably possible to where the present water heater is located. This will reduce the amount of labour and material needed to connect the solar system to the hot water plumbing and the present water heater if it is to remain as the auxiliary heater. This will also reduce heat loss from long pipe runs.

2. The solar storage tank must be located so it is accessible and does not block or hinder access to other components. The storage should not impede passage through hallways or doorways, or be located in such a place as to create a safety hazard.

3. Many solar systems require connections to floor drains in case of an

overflow. The location and accessibility of these drains should be determined during the site evaluation.

Space must also be available for pumps, heat exchangers and for a variety of fluid regulating devices, some of which are large such as expansion tanks.

1.B.2 Structural Considerations For Roof Mounted Arrays

When determining the location for a roof mounted solar collector array, a detailed assessment of the existing structure is required. Far too many solar heating systems have experienced major cost overruns due to difficulties with the structural requirements. While solar collector arrays are becoming far less complex with new innovative designs for collector manifolding and mounting, a sound structural foundation is still a primary concern.

Small Residential Systems

Roofs have little additional roof loading capacity so great care must be taken with choosing how to mount the array. Roofs on modern buildings are generally designed to meet the minimal requirement of applicable building codes. Loads imposed by solar arrays, particularly where the array is raised above the roof slope, can be very large.

Large Systems

The array mounting system must transfer loads to columns, shear walls, or ground.

Most solar systems are installed on roofs of existing, rather than new buildings. The condition of the roof must be accessed in both its structural and its sealing capabilities.

When investigating the roof's structural capabilities, the roof is inspected and structural engineering calculations are carried out. In steel structures, where the strength of the steel is unknown, the steel may be tested instead of using conservative strength estimates from the codes. This permits larger roof loadings and may reduce the quantity of framing required. It may be wise at times to confer with the structural firm who originally designed the building.

Local wind gusts or snow accumulations caused by neighbouring buildings or topography should be observed and determined as not being abnormal.

It is also important to consider potential snow drifting patterns on the roof as a result of collector placement. Work examining this problem is currently underway. It appears, as a general rule, that a clear height of at least one meter between the roof and the bottom of the collectors is required.

It is important to assess the condition of an existing roof before solar collectors are installed. If the roof was in poor condition before the collectors were installed, the contractor may falsely be blamed for damaging the roof by his installation. Repairs will also be much more difficult when the array is in place.

Because any roof penetrations will risk the chance of water entering and possibly incurring damage to the building, we should check:

- Whether the roof will need repair or resurfacing in the near future; if it does, the repair work will be much easier before solar collectors are installed.

- That the roof drains adequately; it will be difficult to seal roof penetrations which are continually submerged.

- If pipe penetrations can be made at any convenient location or are they restricted to specific areas.

1.C MAINTANENCE CONSIDERATIONS

When a solar system is contemplated for a particlular application, consideration of the availability of operating personnel is important. This is a particular concern when the solar system will be the most complex system in the building, or where it will be the only sophisticated mechanical system.

Because solar systems usually have an automatically activated backup system, assessment of the solar system's operational status is not always easy. With conventional space heating or water heating systems, a failure is usually noted by the users or building occupants and quickly reported. With a solar sytem where the backup activation is automatic, the users or building occupants will not in most cases be aware of a solar system failure. In these cases it must be left up to experienced and qualified operational personnel to continually monitor the status of the system.

If the required personnel are not available, the installation of the system may be very unwise.

SUMMARY - Section 1

Evaluating opportunities for solar energy systems is an important initial step to designing a solar installation, which is cost effective, efficient, requires minimal maintenance and which is in fact necessary. The solar system designer should proceed through the following checklist to ensure that he has considered all aspects of obtaining so called "free solar heat":

good assessement of load _____
load profiles _____
can load be modified to suit solar system _____
are any energy conservation plans to be brought forth _____
smooth integration with existing heating system _____
structural adequacy of roof, if collectors are to be roof mounted _____
obtaining accurate design load data _____
collector placement (shading, vandalism, dirt) _____
maintain piping slopes _____
maintenance requirements (complexity of system) _____
space requirements (collectors and all associated mechanical and electrical equipment _____

2. PRACTICAL DESIGN CONSIDERATION

2.A LOAD EVALUATION

In order to match the load to the available solar radiation we must determine the magnitude of the load and how it varies on a daily, monthly and seasonal basis.

A laundry washing facility may require more hot water in the early part of the week rather than the latter part. A bottle washing company often requires more hot water for washing bottles in the summer months.

To measure the energy used we may check fuel or electrical billings. When these are not specific enough we may want to monitor the load. A combination of the following instruments may be used:

- Kilowatt hour meters may be used to measure electrical consumption; a single meter may be read for total electrical usage or individual meters may be installed to determine individual equipment electrical usage.

- Flow meters may be used to measure the fuel consumption or quantity of heated water which is used.

- Thermometers tell us the flow temperatures and give us an added indication of the amount of energy required.

- An energy meter, looking at the hot and cold water temperature, as well as the flow rate, can be installed.

The data may be manually or automatically recorded. The collected information (temperature, flows and energy consumption) is transformed as a load profile which outlines daily, weekly or monthly peaks.

With this information the feasibility for a solar system may be judged. The contribution of a solar system may be increased if the load can be altered to suit the collected energy patterns.

In many cases, patterns for energy consumption in a process are set by historical considerations and are not necessarily fixed. As an example, some plants operated at peak load during night time hours to obtain

preferential off peak electrical rates. With the introduction of a solar system, it may be advantageous to shift peak operations to daytime periods, dramatically reducing solar storage requirements.

In other cases energy may be required for infrequent batch processing of items. If some latitude in timing is available, the effectiveness of the solar system can be dramatically increased if this batch processing is coordinated with available solar radiation.

2.B SYSTEM TYPE CONSIDERATIONS

There are two main types of solar systems; Air systems and Liquid systems.

Air systems require the movement of large volumes of air between components, comparatively bulky storage media and large air handling units. These make space requirements, especially in a retrofit situation, difficult to meet. Air systems can be expensive to install because of the effort required to seal and insulate ducting and components.

Liquid systems are more common in the larger installations we are most interested in. There are a number of different types of liquid systems, usually classifed by the freeze protection method employed.

- Closed loop

- Drain back

- Drain down

Each type of system has some inherent differences, requirements and cautions in design.

Closed loop systems use a glycol solution for the heat transfer fluid. Ethylene glycol is toxic and precautions, such as double wall heat exchangers, must be used to ensure that potable water is not contaminated by fluid leaks.

Propylene glycol is more expensive and is less toxic, but many local codes require the same precautions as with ethylene glycol.

Closed loop systems require facilities to fill the system and bleed off any air in the system. This is often neglected in the design.

With closed loop systems the fluid remains in the collectors at all times. In periods of high solar availability and low load the collectors can stagnate. The high temperatures can boil off the fluid and cause a breakdown of the glycol which results in an acidic corrosive fluid. Therefore, closed loop systems should have some method of protecting against over temperature. This is usually done by having a heat rejection coil or dumping of heated water to create an artificial load.

Pipes and valves should be arranged so that the collectors cannot be isolated without provision for pressure relief. Stagnation under these conditions could result in a dangerous pressure buildup.

The properties of glycol requires special attention in piping methods. Glycol will leak where water will not. This often requires special seals for items such as heat exchangers and coils. Glycol is not compatible with some materials so all components must be specified as suitable for glycol service. Most expansion tanks specified for use in PUSH solar heating systems have butyl rubber diaphrams that decompose over time due to chemical reaction with propylene glycol. With propylene glycol EPDM diaphrams must be used. Glycol also expands significantly over the temperature ranges in solar systems so an expansion tank of some sort is required.

Drain down and drain back systems require special attention to their piping design to ensure quick and complete draining of the system.

Drain back systems require pumps of higher head capabilities than closed loop systems to overcome the static head of the system before the establishment of the syphon effect.

Multibank drain back systems exhibit another common problem. If a syphon is established in one or more banks before others, the pump may not be able to fill the other banks. This problem is usually combated by the use of oversize returns so a syphon cannot be established or by restricting the return lines of individual banks. Automatic flow setters on the return lines at each bank accomplish this and simplify flow balancing of the array.

Drain down systems have fallen into disfavour in Canada because of poor experience with the reliability of the drain down controls. This has resulted in freeze up of a number of large systems, causing extensive and expensive damage to the arrays. If a drain down system is proposed, failsafe freeze protection controls are an absolute necessity.

2.C ARRAY MOUNTING

2.C.1 Types of Mounting

Numerous methods are available for mounting collector array. These vary with the choosen location for the array, either ground, wall or roof mounted.

In this section we will deal mainly with the design considerations for roof mounted arrays as these are by far the most common and present the greatest problems.

If the roof to which the collectors are to be mounted is flat, the collectors will have to be tilted at an angle to the roof. If the roof is sloped the option exists for either mounting the collectors parallel to the roof or sloping them at an angle to the roof.

Arrays Mounted Directly on a Sloped Roof

If possible, mounting the collector array on a sloped roof is usually the simplest and cheapest mounting method. The optimum slope for the collectors is determined primarily by the type of load and latitude of the location. The collector performance is reduced when the slope is off optimum but by very little if the difference is less than fifteen degrees. It is often much cheaper to mount an array on a sloped roof, and if necessary, to use extra collectors to make up the performance difference due to off optimum conditions than to incur the expense of a mounting frame.

Direct mounted collectors are best installed away from roof edges to :

- facilitate installation

- reduce wind loads and the danger of falling snow and ice

- facilitate piping

There should be drainage beneath collectors. A minimum of 50 mm allows for drainage and ventilation beneath the collectors. This limits the possibility of water ponding and fungus growth.

For arrays mounted directly on a pitched roof, the collectors can be

mounted anywhere on the roof, if the collector and hardware weight is small as compared to design snow loads. This is usually the case in Canada.

Examples of Mounting Methods

CASE 1. Truss of Rafter Roof (which has access to attic)

- spanner mounting is recommended when attic is accessible.

- in this case collectors are usually placed high up on roof to allow working space inside the attic.

CASE 2. Joist Roofs and Cathedral Ceiling

- collectors can be lag bolted to joists.

- the location of the array on the roof will be influenced by piping runs, ease of fastening, and asthetics.

The lag screws must be mounted in pre-drilled holes in the centre of the structural timbers. As least 50 mm (2") of the lag screw's thread must penetrate into the timber.

Finding the joists can be a problem. The most common method is to drive small nails through the sheathing until both edges of the timber are located and to measure to the centre of the joist.. The holes can be sealed with silicone sealant or equivalent. The lag screws must also be well sealed with silicone in the pre-drilled holes and over the head of the screws.

CASE 2. Alternate

A modification of the spanner mounting method may be used on cathedral ceiling if one is willing to break into the finished ceiling to secure the threaded rods and then repair the ceiling.

Raised Mounted Arrays

Raised mounted arrays can collect snow and are subject to high wind forces; these forces are transferred down the support frame and applied as point loads to the roof structure.

Collectors are raised off the roof by a support system in order to give them an optimum tilt angle.

On smaller and residential systems mounting racks are placed directly on the roof. On larger projects, framing members span the roof and transfer loads to the roof support points. The collector mounting racks are then attached to this framing. On these projects, roof inspections and collector mounting designs are usually done by a structural engineer.

Smaller residential projects may be designed by specially prepared handbooks or come as packaged systems.

No attempt will be made here to design collector racks, but rather, to show attachment methods to roofs and mounting methods so as not to damage the roof membrane. Although structural considerations are very important, these are common knowledge to qualified people, whereas adequate methods of penetrating, fastening to, and sealing roofs with collectors are not.

It is essential to know how roofs behave and how they are built up before designing a mounting method. The condition of an existing roof must be assessed prior to the solar system installation so that faults which develop in the roof are not automatically blamed on a bad installation. If the roof must be repaired, do it before installing the array.

Problems are likely to develop on roofs that do not drain or roofs in which drainage is impeded by curb mounts for collectors.

Adequate clearance must be provided between collector rows and between the bottom of the collectors and the roof for future maintenance or resurfacing.

The following are **not** recommended in the installation:

- pitch pots because they require maintenance.
- eye bolts fastened directly to the roof decks.
- use of parapets as collector supports.

CASE 1.

Raised mounted array fastened to pitched roof by spanner mount method or by lag bolting to roof joists.

CASE 2.

Raised mounted collectors on flat built up roofs (curb support) as in Figure 2.C.1.1.

Note:

1. Aggregate removed from membrane
2. The membrane is cut open and the insulation is inspected
3. Because loads cannot be borne by the insulation, wood blocking is placed on the structural slab to support the curbs.
4. Roof membrane is nailed to blocking and curbs are installed
5. Curbs are anchored to slab.
6. Wood cant strips are placed alongside mounting blocks to provide a base for a bitumous flashing which will seal the roof membrane.
7. The top of curb is flashed and aggregate is placed around the mounting block to provide U.V. protection for flashing and roof membrane.
8. CAUTION: Long curbs placed at right angles to roof slopes may act as dams and prevent water from reaching the roof drains. Curbs should be divided into sections no longer than one metre.

CASE 3.

Column supports - These may rest on structural members of roofs or they may pierce roof to transmit loads down to floor slabs or footings.

See Figures 2.C.1.2 and 2.C.1.3

Note:

1. Aggregate and insulation removed
2. Column welded to and bearing on structural section
3. Pitch pocket box of exterior type placed over column and flashed with bituminous flashing to roof membrane.
4. Space in pitch pocket box filled with mastic
5. Hood and flashing placed over pitch pocket box and sealed with caulking.

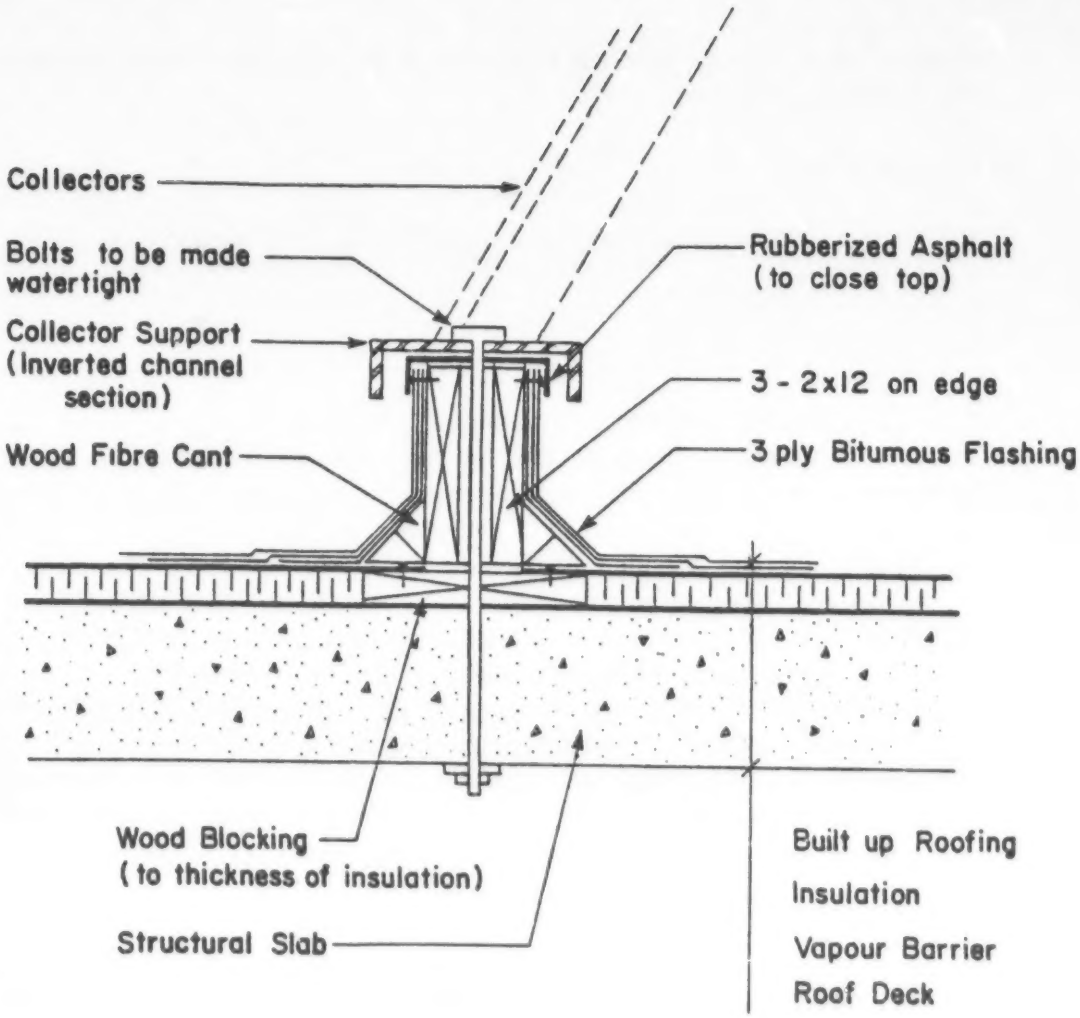

FIGURE 2·C·1·1
(from D.P.W. Briefing Document S-2)

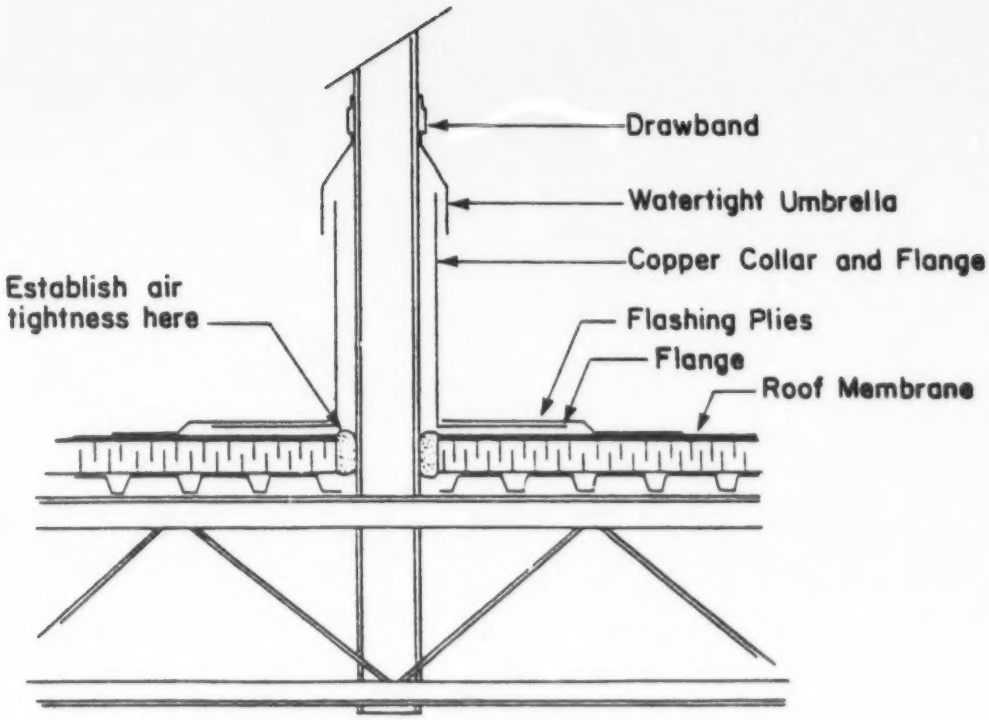

FIGURE 2·C·1·2
PIPE COLUMN SUPPORT
(from D.P.W. Briefing Document S-2)

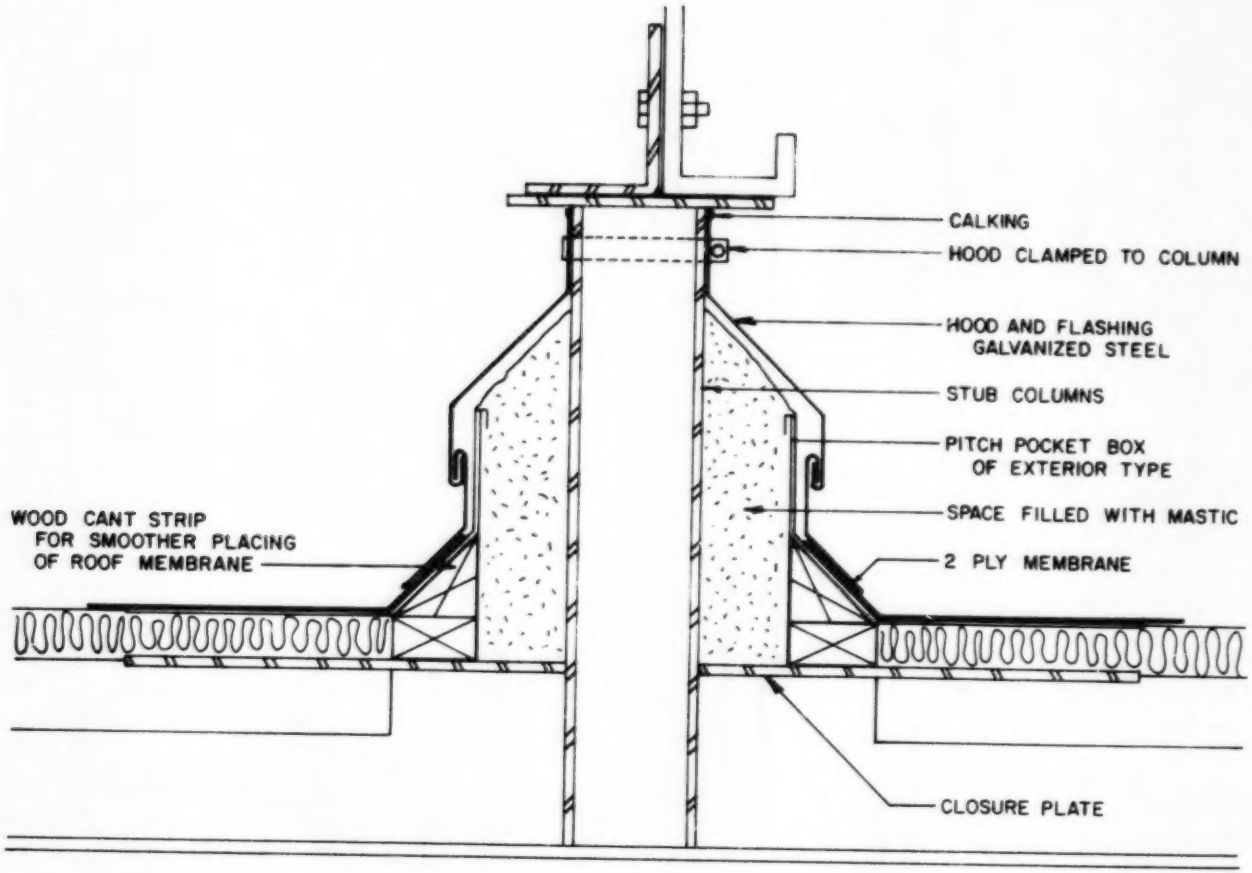
CALKING
HOOD CLAMPED TO COLUMN
HOOD AND FLASHING
GALVANIZED STEEL
STUB COLUMNS
PITCH POCKET BOX
OF EXTERIOR TYPE
SPACE FILLED WITH MASTIC
2 PLY MEMBRANE
WOOD CANT STRIP
FOR SMOOTHER PLACING
OF ROOF MEMBRANE
CLOSURE PLATE

FIGURE 2·C·I·3

2.C.2 Pipe Slope Requirements

Maintaining adequate pipe slopes is imperative for drain back systems because these rely on gravity drain back freeze protection. Glycol systems require pipe slopes for draining and flushing.

A minimum 1 in 50 pipe slope should be used on all systems. For drain down or drain back systems, this minimum slope is critical to the continued operation of the system. For closed loop glycol systems, sloped piping will allow for complete system draining, should replacement of the glycol be necessary. With large solar systems, where rows of collectors stretch for 50 metres or more, considerable height must be available beneath the collectors for pipe slopes.

Pipe mounting methods must be adequate to ensure that the pipes do not sag and reduce the original slope. This is especially true for thin wall and plastic piping materials.

2.D AIR SYSTEMS

2.D.1 Practical Aspects of Collector, Duct and Damper Sealing

In recent years the use of air type solar systems has been dramatically reduced and very little development effort is being expended on components for air systems.

Air systems, although extremely simple in concept, have proved very difficult to apply practically. Solutions to problems of collector, duct and damper leakage have proved costly to solve and these problems alone have, in many cases, negated the theoretical effectiveness of an air type solar heating system.

Some good applications for air systems do exist; however, they are very site specific. Some applications for air systems that can be considered are:

- Preheating make up air to large buildings which presently have necessary interior distribution ductwork.

- Preheating process hot air in specific commercial applications such as drying operations

- Drying of agricultural products such as grain. Although grain drying is only a seasonal application, it can be very practical in that it has a tremendously high load which utilizes every bit of energy produced from a solar system.

These application generally require a very low grade of energy.

Leakage is a major problem with most duct systems. Failure to adequately seal ducting will result in low thermal performance. For this reason, it is recommended that every duct joint be sealed with suitable tapes or sealants. Rectangular galvanized ducting used in home space-heating is not recommended as it is very difficult to seal adequately.

Some pre-insulated fiberglass ducts are available. These are generally more expensive than galvanized ducting, but save much of the installation time, and are usually much easier to seal effectively.

Sealing of the collector array is a very important consideration. This includes both connections between collectors, as well as leakage in the collector unit itself. Collectors must be carefully examined before installation to ensure that shipping has not damaged the various seals. Great care must be taken in sealing the connections between collectors.

Field experience from a number of systems has shown that:

- In order to limit leakage between collectors great care must be taken when aligning them.

- If silicone sealant is used on metal surface, better results are obtained if the surfaces are first coated with primer.

- The ducting system should be tested for leakage prior to insulating.

Glass wool and urethane insulations are the most widely available for insulating air ducts. Ducts should be insulated to at least RSI 1 (R-6) outside and RSI 0.5 (R-3) inside.

Ducting penetration into building must be done with great care to avoid both water and air leakage problems.

2.E COMPONENT SELECTION - LIQUID SYSTEMS

2.E.1 Heat Exchangers

Heat exchangers for liquid systems transfer the heat from the liquid in the collector loop to the liquid in the storage loop. These heat exchangers must be properly sized to get good system efficiency.

Double walled heat exchangers are required with systems that use potentially toxic fluids with the domestic water supply. These heat exchangers have two walls separating the fluids, so that if either wall develops a leak, the fluid enters the cavity between the walls rather than mixing with the other fluid. These exchangers usually allow any liquid entering the cavity to drip out onto the floor, thus providing visible evidence of an internal leak. CSA Standard F-379 sets out the requirements for the type of heat exchanger that should be used for package domestic hot water heating systems. Local inspectors, however, may require additional levels of protection.

Thermosiphon and drain down systems do not use heat exchangers because the domestic or process hot water is circulated directly through the collectors. Drain back systems require only a single wall heat exchanger because both fluids are water.

Internal heat exchangers are those where a coil or tank is immersed inside a storage tank. With external heat exchangers both fluids are contained in a passage where they flow past each other in opposite directions.

There are a variety of types of heat exchangers for small solar systems:

Tube heat exchanger placed in a tank - has flexible copper pipe shaped into a coil, with or without fins and secured inside the tank.

Wrap-A-Round heat exchanger - has a tube wrapped around and bonded to the outside of the tank. This type of heat exchanger is effectively double walled and is sometimes used on closed loop systems with potable water in the tank.

Parallel tube heat exchanger - consists of parallel tubes in continuous contact with each other (soldered together) where water and heat transfer fluid flow in different (counterflow) directions.

Tank in tank heat exchanger - has a single wall tank placed inside an outer

storage tank. The heat transfer fluid is in the outer tank and, as an option, the inner tank may come with a coil wrapped around it.

On large systems one finds:

Tube in tube heat exhanger - has a tube fitted inside a tube (both tubes are copper). The heat transfer fluid flows in the inner tube which can be double walled with leak detection passages. Water flows in the outer tube. Fluid flow is counterflow. Sizing of heat exchanger is accomplished by adding heat exchangers in series.

Tube in shell heat exchanger - has an outer casing or shell surrounding a bundle of tubes. These are single wall types which are usually used with drain back systems. In many cases the tube bundle is placed directly into the storage tank through a port in the side.

Plate type heat exchangers - has counterflow fluid flow through heat exchanger plates. Plate type heat exchangers may be easily custom fitted to the flow requirements by adding or removing plates.

Heat Exchanger Advantages/Disadvantages

1. External heat exchangers which are not immersed in any fluid are easier to inspect and service.

2. Double walled heat exchangers are more expensive.

3. Custom made heat exchangers or heat exchangers which require special metals require long delivery times.

4. Plate type heat exchangers are expandable should the system be enlarged.

2.E.2 Pipe Systems

The piping system discussed here includes not only the piping itself but the various other associated components found in the system such as valves, expansion tanks and pipe hangers not covered elsewhere.

Piping for a solar heating system can account for a major part of the installation cost. Although most solar systems still use either copper or iron pipe, an increasing number are being constructed using plastic piping materials. This practice is particularly prevalent in small domestic solar water heating systems.

Piping runs, both inside and out, should be made as inconspicuous as possible so that the finished installation has a good appearance.

Collector piping should be kept as short as possible. This is usually possible when the collectors are centrally located to the system operating room. Long runs of piping are subject to damage, increased heat loss and pressure drops which require larger pipe sizes.

Piping should be carried out to ensure tight joints and no chance of corrosion at the joints.

- If different metals are to be used, isolate them with dielectric couplings.

- Use materials compatible with the working field. As an example, don't use zinc galvanized piping to carry glycol solutions.

Straight pipe runs longer than 25 metres should have expansion joints to prevent strain on the joints. Normally, bends and elbows are adequate to take up the expansion.

A minimum pipe slope of 1 in 50 must be used on all systems to allow acceptable draining. Plastic pipe should be sloped 1 in 30 because of the potential for sagging with time. It is good practice to install plastic pipe with continuous support over its entire length.

Ensure that the required valves and safety relief devices are included in the design. The following valves and safety devices are normally used in piping systems:

- expansion tank (closed loop)

- pressure relief valves

- air vents

- vacuum breakers (drain back)

- check valves

- strainers

- filling assembly valve

- flow control

- tempering valve

When incorporating valves into the system design, be sure that no portion of the system, such as storage tank or a row of collectors, can be isolated from the pressure relief valve intended to protect it. In the case of collectors, automatic air vents can not allow vapour to escape at sufficient a rate to protect a bank of collectors in the event it is isolated at its inlet and outlet.

In the specification of piping systems an area often overlooked is the suspension of the piping. Improperly suspended exterior piping has led to a significant number of solar system failures.

It is not sufficient to leave the design of the pipe hanging system to the imagination of the installation contractor.

Hangers should be of a standard type with proper shield or solid inserts to protect the insulation. Threaded rod used for suspending pipes must never be bent.

Pipe hangers should be spaced using the plumbing code requirements as minimum. Care must be taken to adjust hangers so that consistant slopes are maintained. Where pipes are suspended from points which might incur some differential movement, additional allowance must be made for this movement.

2.E.3 Types Of Piping

The actual selection of materials, fittings and components is dictated by the local plumbing codes. In selecting piping materials we must consider:

- the temperature extremes to which the piping will be exposed; (this will most affect solder joints and plastic piping)

- the vulnerability of piping in outdoor areas;

- the fluid that is used (some fluids react chemically with certain types of piping)

Copper Piping Systems

There are three basic types of copper piping used in domestic plumbing systems:

Type M - lightest copper pipe currently acceptable for use on solar systems; common domestic plumbing situations.

Type L - thicker wall than type M; also common in domestic water plumbing;

Type K - thick-walled for use on high pressure applications; underground piping must be Type K.

Some effort is being made to persuade inspection authorities that, because of the low pressures encountered in most types of solar heating systems, the use of very thin walled copper piping is acceptable. The type of piping being suggested is DWV piping intended for water drainage services. If this type of piping is found to be acceptable, the overall cost of piping systems could be somewhat reduced.

The use of flexible copper pipe is not recommended because of the difficulty in ensuring adequate slopes on the piping, and the poor appearance usually associated with flexible copper piping installations.

Type M, L and K hard copper piping is acceptable in most jurisdictions for use in hot water piping systems. Type K, which has a greater wall thickness, is recommended in solar heating systems where the piping may be subjected to physical damage, such as with ground-mounted collector arrays.

Galvanized Threaded Pipe

Galvanized threaded pipe may be used with water or process hot water. Teflon tape should be used with all pipe fittings. Corrosion protection (gaskets) should be provided at connections to copper or other pipe. Water will eventually corrode galvanized pipe. Galvanized pipe must not be used with glycol solutions.

Black steel piping

Black steel piping is used on glycol loops. Where large runs of pipe are to be used it is cheaper than copper pipe. Pipe fittings should use teflon tape and be protected against corrosion at the connection of dissimilar metals.

Stainless steel pipe

Stainless steel pipe is used with corrosive fluids or where conditions dictate special contamination considerations.

Flexible epoxy fiberglass

Flexible epoxy fiberglass is used beneath roadways where there is a danger that other pipes may break.

Plastic Piping Systems

The use of plastic piping is, in cases, restricted by local fire regulations which do not allow plastic materials in commercial or industrial buildings. Where allowed, two types of plastic piping have been found acceptable. These are CPVC and Polybutalene.

CPVC piping is joined with a solvent weld, threading, or mechancial couplings. When using CPVC pipe in solar systems only solvent welded joints are recommended. Only special CPVC cleaner solvent and cement can be used. Note that the solvents and cements used with ABS and PVC are not suitable for CPVC piping. Joints made with inappropriate solvents and cements will likely leak or fail entirely. CPVC will sag significantly at about 70°C, and must be supported every 1 metre where it runs horizontally.

Where polybutylene piping (PB) is used in the vicinity of copper piping, care must be taken to ensure soldering paste does not come in contact with the plastic piping because it causes severe deterioration of the

plastic compression fittings. PB piping also has a minimum bending radius which must be observed during installation to prevent the pipe from collapsing.

Polybutylene pipe systems can be joined with insert compression fittings or with heat-of-fusion techniques. When using PB piping with solar systems, only compression type fittings are recommended. Some solar manufacturers provide pre-insulated PB pipe for solar installations. PB piping will begin to sag at about 92°C.

2.E.4 Collector Interconnection

In the area of liquid solar heating systems a number of developments have taken place. Single header collectors have been developed both in the form of flat plate collectors and evacuated tube collectors and these types of designs have greatly simplified the installation of solar collector arrays.

Collector interconnections have presented numerous problems and no one type of interconnection system has been immune. Interconnection can be classified as expansion or non expansion type and as solid or flexible.

The various collector manufacturers specify the maximum number of collectors that can be coulpled is series without the use of some expansion device.

Collector interconnections must be able to:

- take up expansion and contraction between collectors while minimizing stresses in the couplings.

- prevent leakage at collector couplings

- prevent galvanic corrosion

The materials used for collector interconnections must be:

- durable

- resist weathering and sunlight

- compatible with heat transfer fluid

Copper Pipe Connections

Because of high temperatures in the vicinity of collectors, 95/5 tin/antimony solder should be used.

Where more than six or seven collectors, or as specified by the collector manufacturer, are mounted together, some provision for thermal expansion must be made. This limit prevents expansion and contraction from putting too much strain on the joints and sealing materials.

The major disadvantages of this type of connection are the precise alignment requirements and the difficulty in removing a single collector at a later date for repair.

Hose Connections

Some non-metallic hose connections are made with:

- EPDM

- VITON (fluoroelastomer)

- SILICONE

A preferred connection used with internal headers is silicone hose held in place with silicone caulking and stainless steel gear clamps. It is preferrable to use clamps on pipes which have ferrules. The type of connection can easily be damaged by improper tighting and often will require several retightenings before a perfect seal is obtained.

Victaulic Couplers

Used for connecting internal headers, they have EPDM gaskets and temperature ranges up to 170^{o}C (Victaulic 77). Expansion bellows are often used with victaulic couplings. This type of coupling requires precise alignment of the headers, but allows for easy replacement of collectors. This type of interconnection is difficult to insulate.

2.E.5 Building Envelope Penetrations

Solar piping may enter a building in many different locations. Roof penetrations are very common and wall penetration may be above or below grade.

All penetrations require a tight and lasting seal. It is important that pipes be restrained firmly where they enter and that the space around the pipes be well sealed.

When penetrating a shingled roof, aluminum, rubber flashing flanges or boots are used, as illustrated in Figure 2.E.5.1. The flange is sealed at the pipe with a neoprene collar. The pipe insulation stops at the flange collar and does not penetrate through the building. This prevents any water from entering the building from beneath the insulation material. At the roof level the flange is mounted with the upper portion placed beneath and the lower portion above the shingles.

When penetrating flat roofs, pipes may be sealed inside of pitch pocket boxes as shown in Figure 2.E.5.2. The pipe is sealed inside the box with a sealing compound and caulking. The exterior of the pitch pocket box is sealed to the roof with a bituminous membrane and flashing.

Wall penetrations must maintain the minimum horizontal pipe slopes. A separate hole a few mm larger than the pipe is required for each penetration. Pipes are sealed to the wall with caulking as shown in Figure 2.E.5.3.

Underground pipes, because they need protection against ground settlement at the wall, should be inserted in a steel pipe, which also passes through the wall and extends for a few feet on the other side. The sealing is accomplished with caulking.

2.E.6 Underground Pipe Runs

Underground pipe runs are expensive, cannot be routinely inspected and are to be avoided except for circumstances where they are absolutely necessary.

If copper pipe is used, underground piping must be of type K. Piping should be buried beneath the frost line and properly bedded to prevent rocks or other objects from puncturing the pipe or insulation and to prevent settlement.

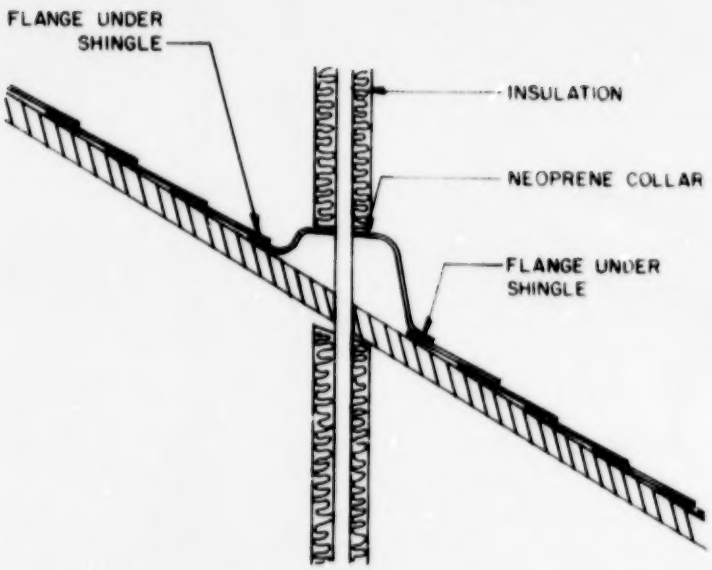

FIGURE 2·E·5·1
PIPING ROOF PENETRATION

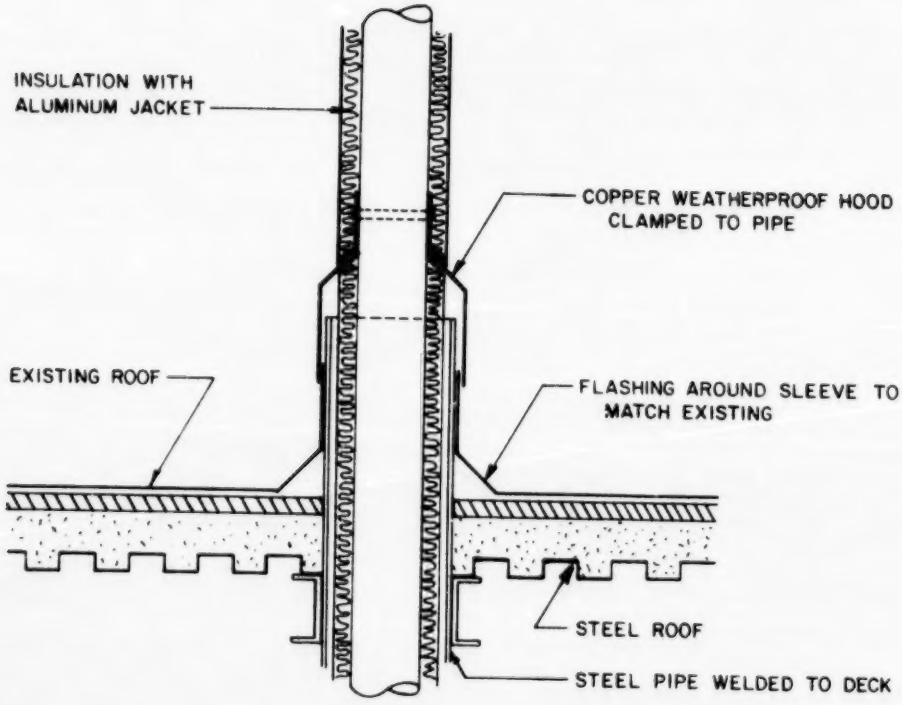

FIGURE 2·E·5·2
PIPING ROOF PENETRATIONS

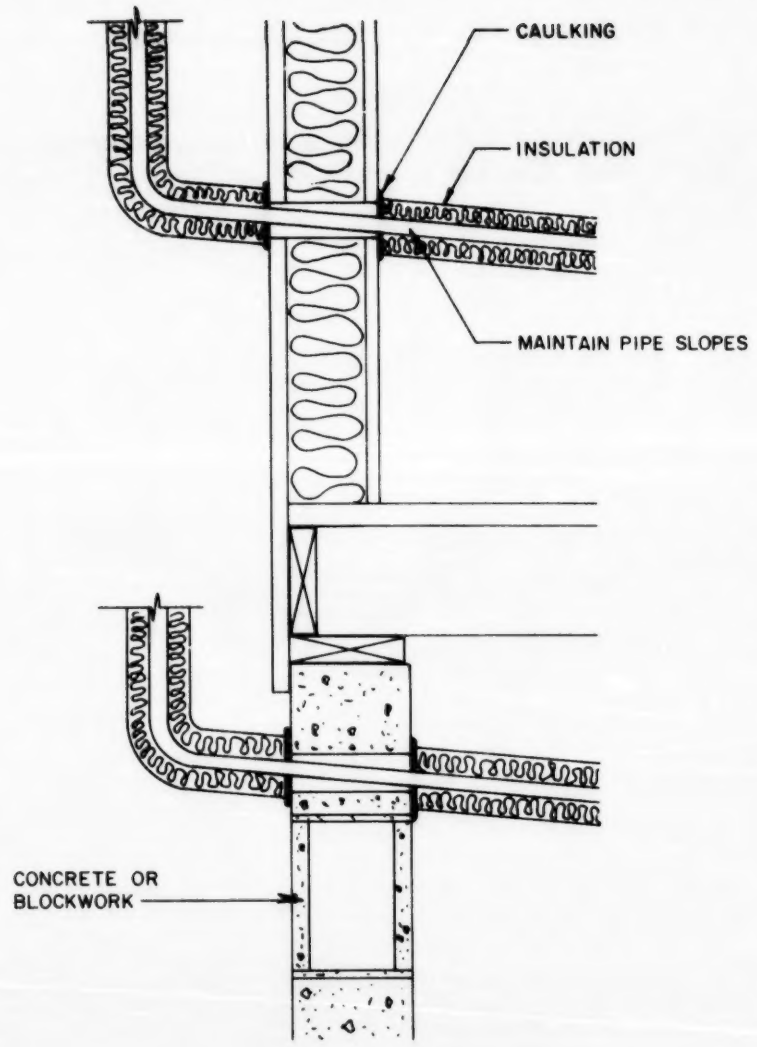

FIGURE 2·E·5·3
PIPING WALL PENETRATIONS

The recommended minimum insulation level is RS1-1 (R-6). It is important that the insulation remain dry. The insulation should contain as few joints as possible.

Where piping runs through or under a foundation it should pass through in iron pipe sleeves, with the sleeve filled with sealant.

2.E.7 Insulation Requirements

The insulation of solar heating systems is an extremely important consideration in the installation procedure. Without proper care in the insulation of piping and components in a solar heating system, many of the benefits of an otherwise well designed and installed system will be lost.

The insulation of a solar heating system also goes a long way to producing either an acceptable looking installation or an eyesore. In order to produce an acceptable looking result, insulation must be selected and applied with care, both inside and out.

When insulating a solar system the storage tanks are an important consideration. The overall heat loss from a poorly insulated solar storage tank can be very significant. Insulation methods, standard in the mechanical industry, are generally acceptable in this area.

Selection of Insulation Materials

There are two major considerations when selecting insulation materials for solar applications. These are:

- proper insulation levels,

- conditions to which the insulation will be subjected.

Levels of Insulation

The selection of the proper levels of insulation for the various components of a solar heating system must be based mainly on an economic evaluation. As levels of insulation are increased, not only does the cost of the actual insulating material increase but also, there are increased costs for insulation jacketing, pipe hangers and installation. As a minimum requirement the following insulation levels should be used:

- RSI-1.0 (R-6) for exterior piping,

- RSI-0.5 (R-3) for interior piping.

Insulating Materials

When selecting insulating materials, particularly for interior use, code requirements for flamability, flame spread and smoke generation, must be considered.

Numerous insulating materials are available for use on the piping of solar heating systems. The most commonly available materials are:

- Glass fibre,
- Urethane or isocyanurate foam,
- Elastomeric,
- Polyethylene.

A major criteria for the selection of insulating materials is the conditions to which it will be exposed.

Glass fiber insulation is very susceptible to absorption of moisture and, hence, must be extremely well sealed in outdoor applications. It is bulky in comparision with the alternatives. This type of insulation should not be used on the exterior portion of a solar system.

Urethane and isocyanurate insulation are not susceptible to moisture absorbtion and are less bulky than glass fiber insulation but are relatively expensive. These materials are the best choices for exterior use. Special premolded corners and tee sections are available from most manufacturers.

Elastomeric insulation has a relatively high thermal resistance for its thickness and does not absorb water; however, it is susceptible to deterioration from ultra-violet radiation. Protective paints are available but they must be applied frequently and have not, in many cases, been proven effective. This type of insulation can be applied to the piping by slipping it on before soldering the pipes together. It must simply be pushed away from the joints being heated. Elastomeric insulation tends to shrink with age; therefore, it should be compressed by at least 5% during installation.

Polyethlene insulations are ultra-violet resistant, do not absorb moisture and are relatively inexpensive; however, they are not intended for use above 100°C and, hence, are not suitable for use near collectors which may stagnate.

It is advantageous from both cost and durability standpoints to consider using different types of insulation for interior and exterior applications.

Weatherproofing and Protection

The protection of insulation from degradation has several facets:

- protection from water absorbtion,
- protection from ultraviolet deterioration,
- protection from physical damage.

As discussed earlier, some materials are subject to either of the first two problems while, in general, all materials are subject to the third problem.

If non-waterproof insulation is used in outdoor applications, it must be extremely well jacketed if it is to be of any real long term value. The following rules should be observed:

- all seams must point downward,
- all exposed devices, other than those that must be uprignt for proper operation, such as automatic airvents, must project downward,
- all joints in the jacketing must be sealed with a sealer and/or tape approved for the purpose. It is best to obtain the tape supplied by the jacket manufacturer for the purpose. Duct tapes or electrical tapes are are not acceptable.
- termination of insulation at the connection to collectors must be completely sealed to both the outer insulation jacket and the pipe itself. Sealants used for these purposes must be capable of withstanding the extreme temperatures of stagnation that might be encountered.

For these reasons, a water absorbing insulation, such as fiberglass, should not be selected for exterior use. Urethane and isocyanurate insulations have proven to be best for exterior application because of their low water absorbing characteristics.

Most insulating materials are acceptable for indoor applications with the major criteria for the installation of all types being the same - completeness and neatness. The fire ratings of insulation such as elastomeric type, must, however, be considered.

Insure that all piping carrying hot water is insulated, including any piping between the solar storage tank and the auxiliary storage tank. All valves and test points installed in these lines should also be insulated.

Miter all angled joints in the insulating material if preformed elbows and tees are not used. Tape all joints with a tape of the same colour as the insulation jacket and in no case use electrical or masking tape for this purpose. Tapes are available for use with most types of jackets from the the manufacturer. The manufacturer can be consulted for his recommendations.

Insulation Safety Considerations

The basic purpose of pipe insulation is to reduce heat loss and, hence, increase the efficiency of the solar system. Another purpose that is also of great importance is protecting people from burns.

It must be remembered that solar heating systems can produce water of very high temperature. Water or fluid of this temperature will be circulated, at times, through the loop between the solar storage tank and the collectors. Depending on the plumbing arrangement of the system, high temperature water may also travel from the storage tank to the tempering valve where it is mixed with cold water.

All piping which can potentially be heated to high temperatures must be completely insulated. Valves or other fittings that project through the insulation in these portions of the piping must also covered if they are in areas where they might accidently be touched.

2.E.8 Pumps

Pumps for drain back systems must abe sized with significant capacity to reliably fill the system and establish full circulation. wht the pump drawing from a non-pressurized tank, the minimum suction head requirements for the pump must be considered.

Pumps circulating potable or non-treated water must be either bronze or stainless steel. When glycol is used the pump must be specified with seals and gaskets of suitable materials.

2.F CONTROL SYSTEM STRATEGIES AND TRADEOFFS

The purpose of the controls in a solar heating system is to regulate flows through the various loops of the system in such a way that efficiencies are optimized. A second and equally important function of the controls is to protect the various system components from harmful temperature extremes.

The control logic should be devised to perform these functions in the simpliest fashion possible. Generally, the simpler the controls the more likely they will continue to operate properly and be maintained on site.

The failsafe aspect of control systems is extremely important. Once a design is devised it should be carefully examined to ensure that no simple component failures could cause a drain back or drain down system to stay full in below freezing conditions or for a glycol system to continue to circulate sub freezing glycol through a heat exchanger.

After failsafe operations have been examined, the system must be examined to ensure that, in the event of a primary control failure, the failsafe backup feature will not simply operate the system until the backup control system also fails, without giving the required alarm.

Operation and Options Available on Differential Controllers

Control systems for solar heating systems have changed little in a conceptual way from those developed for the earliest applications. Most solar heating systems are controlled by a differential temperature controller, usually looking at the temperature difference between the solar collectors and the storage system. Great advances have, however, been made in the reliability and the maintainability of control systems.

Numerous control systems now available include diagnostic packages and some are available complete with data acquisition systems which record critical temperatures, flow rates and energy quantities automatically.

Although the more sophisticated of these controllers are only suitable, because of their cost, for large engineered solar heating systems, even the controllers available for small package solar heating systems are substantially improved over earlier models. More reliable sensors are being employed, reducing the incidents of control system failures and added features such as freeze protection and over temperature protection are available.

Sometimes controllers may be faulty, improperly located, improperly installed or incorrectly set. This hinders the operation of the entire solar system. It is important, therefore, that controllers be checked before and during commissioning of solar systems.

Experience has shown that control system problems are one of the primary sources of operation problems and poor system efficiency. Extra attention to selection, installation, set-up, checking and maintenance of control systems is well worth the effort.

The basic on/off differential controller has two temperature sensors. The controller starts the system whenever the temperature difference between collector and storage is greater than a preset amount and stops the system when this temperature drops below a preset amount.

The **proportional flow differential controller** operates the same as the basic type except that it can vary the pump speed. This regulates flow of fluid to the collectors to account for the amount of solar radiation available. This reduces pump cycling and improves collection efficiency.

The **differential controller with protection features** operates the same as the on/off proportional flow differential controllers except that it also has sensors to protect the system from freezing or overheating.

Some controllers behave as data acquisition systems which record other data that is used to judge how well the system is operating.

The control operation of a differential controller has the following basic sequence:

1. Pump is switched on when the collectors are warmer than the storage tank by a preset amount, usually $10^{o}C$.

2. Pump is switched off when the temperature difference between the collectors and the storage drops to another preset value, usually 1 to $3^{o}C$.

3. Most controllers have a built in "fail safe operation" that shuts the pumps off when there is a broken sensor wire. If a system failed in the "on" position, wasted energy and possibly freezing of the system would occur.

Controllers may optionally have:

1. An over temperature protection sensor located in the storage tank which turns off the pump if the storage tank temperature exceeds a preset valve, approximately 70°C.

2. Freeze protection sensors turn off the pump when temperatures in the return piping drops below approximately 5°C. This prevents drain back systems from freezing and prevents glycol systems from freezing water in the heat exchange loop.

Pumps for a secondary circulation loop where service hot water or DHW is heated by circulating it through an external heat exchanger are usually controlled by the same control as the collector pumps. The collector and secondary pumps are then turned on and off together.

Control systems must allow the overall operation to proceed simply and with little manual input. It is to be expected that if control systems are to operate the solar systems efficiently, mechanical equipment must have been well designed and sized.

2.G COMMISSIONING REQUIREMENTS

Commissioning requirements may be divided into two sections; start up and commissioning.

Start up includes a series of tests and inspections conducted by the system installers and witnessed by a representative of the owner of the system. These are performed during and immediately after construction to ensure that the system and its components are correctly installed, capable of operating at specified levels and capable of being commissioned.

Commissioning includes a number of discrete tests. The performance and successful completion of these tests ensure that the installed system meets the design specifications.

Many solar heating systems, employing relatively sound designs, have never operated as expected. In many cases this was due to lack of proper commissioning of the system at the outset. The commissioning of the solar heating system is one of the least understood and most often neglected processes in the entire solar design and construction industry. In recent times this problem has begun to be recognized and substantially more effort is being placed on ensuring that a solar heating system is actually operating as designed before it is signed off as complete.

The proper commissioning of a solar heating system not only ensures the system is operating as designed when the system is complete but allows the setting of bench marks to which system parameters can be compared over the long term and hence ensure the proper operation of the system.

The **start up** work involves the following series of inspections and tests:

1. Site Inspections

The following equipment is inspected:

- Collectors
- Piping
- Insulation
- Thermal Storage
- Electrical

This is the ensure that all equipment:

- is as specified on drawings
- conforms to manufacturers spec sheets
- is correctly installed
- is capable of operating at the specified level
- is capable of later being commissioned.

2. Verification of Glycol Properties

This ensures that the heat transfer fluid:

- is of the proper type
- has required freeze protection

Tests are performed to determine the glycol fluid's reserve alkalinity, concentration ratio and ph level.

3. Differential Controller Test

The following three tests are performed to ensure that the differential controller operates correctly:

- Fail safe operation
- Differential Setting
- Drain back test (on systems using a drain back operation for freeze protection)

4. Motor and Pump Test

These ensure that the pump is installed correctly, with the correct rotation, and its operation meets the manufacturer's specifications.

5. Leak Test

The system is pressure tested to find any leaks in the systems. Leaks should be repaired and the system retested. The system may be tested in sections as construction proceeds, however, a final pressure test of the completed system is best where possible.

6. Final Visual Inspection

During this final inspection the system is checked over to ensure that it can be started up safely. Checks are made to ensure that the system is filled with liquid (closed loop), that there is flow and that manual valves are opened in the specified pattern. Collectors are checked for outgasing which would affect the system performance.

7. Flow Balancing of Collector Loop

This involves:

- measuring collector loop flow rate

- measuring and balancing bank flow rates directly or by temperature

- adjusting final flow rates.

The commissioning work involves the following tests:

1. Verification of Flow Balance

The collector loop is checked for flow and for flow direction. The pump horse power and pressure differential is measured. With these and the manufacturer's pump curve the flow rate is checked. With the system operating the temperature rise across each collector bank is measured and if necessary the bank flow rates are adjusted.

2. Final Flow Adjustment

With the collector flow balanced, a final adjustment of the overall flow rate is made. A dated locking tag is placed on the system's throttling valve.

3. Heat Exchanger Effectiveness

The heat exchanger is checked to ensure that it conforms to specifications. Primary side and secondary side heat exchanger temperatures and flows are measured and the effectiveness calculated.

4. Preliminary Thermal Performance Test

This test assesses the operation of the solar system as a whole, and compares results with the performance claimed by collector manufacturers.

The following data is recorded:

- outdoor ambient temperatures
- collector return temperature
- collector supply temperature
- total collector loop flow

Solar insolation is usually estimated rather than measured. With this data and the density and specific heat of the heat transfer fluid we can calculate:

- the heat gain per unit collector area
- the efficiency (which may then be compared with the manufacturer's claims)

2.H OPERATIONAL MONITORING

The prime purpose of operational monitoring is to detect a decrease in the solar system performance. This is done by regularly comparing certain indicators, such as temperatures, pressures and pump run times with those specified in the design and commissioning process. A change in these indicators outside of the design range means that the system has an operational problem. Identifying operational problems or system breakdowns as soon as possible is important in reducing damage to the system, and will also maximize the energy output of the solar system. Early detection of problems will also increase the life of the system and keep operating and maintenance costs to a minimum.

Checks of instrument readings and verifications of the operation or condition of component equipment are conducted on a set of schedules as follows:

daily,

monthly,

semi-annual or yearly.

Daily inspections involve visual checks of:

- system pressures,
- pump operation in relation to weather and control modes,
- system temperatures in relation to control modes,
- status of system alarms,
- evidence of leaks or pressure relief valve activation.

These indicate whether there is an immediate malfunction or not.

Monthly checks involve a more detailed examination of items that are checked daily. The recording of the information provides an historical record of the system's performance.

Semi-annual checks involve a detailed examination of the system. Many of the tests required in the startup and commissioning phase are repeated.

Some typical semi-annual checks are:

- fluid quality checks

- control system checks for:
  - sensor mountings security
  - calibration of sensors

- check on condition of filters and strainers

- testing of valves to assure functioning

- fluid level in expansion tank

- heat exchanger effectiveness test

The system design must include sufficient instrumentation to perform the daily and monthly checks. A typical package would include:

- one pressure gauge for each pump which can measure inlet and outlet pressure selectively

- a run time meter and event counter on the collector pump(s)

- temperature gauges measuring key system temperature including collector supply and return and storage temperatures.

Continued Operation of the Solar System

Once a solar heating system has been designed, constructed and commissioned, it must then be cared for. Much more emphasis is now being placed on the proper documentation of systems and the preparation of operating manuals.

Manuals are essential to the successful operation of any mechanical system. They must clearly explain the operation of the system, contain the necessary operational checklists and detail troubleshooting procedures for when a fault is found or suspected. These requirements are really no different than for any other complex mechanical system, but have often been neglected in the solar industry.

In the past, the production of manuals was generally left to the contractor constructing the system, with varying amounts of input from the design

consultant. The operations manuals for many solar systems consist merely of a collection of component brochures. Although this information is important, it is only one small part of an operations manual.

Significant improvement in operating manuals has taken place recently, mainly through efforts of the various funding agencys. As an example, solar systems now constructed under the federal government PUSH programme require that manuals for the commissioning, operating, and troubleshooting be produced as part of the documentation for funding approval.

SUMMARY - Section 2

Being practical in the design considerations implies a familiarity with solar systems; it means using experience which has been gained from past problems associated with solar installations. In this way many of the tried and tested methods do not have to be tried over again if they were unsuccessful the first time. Truly useful or accurate data on solar systems can often only be obtained from a monitoring program.

The following checklist will provide the designer with some important considerations.

Accurate measurement of load (instrumentation, past consumption)

Choice of system type

- best suited to situation
- climate
- complexity
- reliability

Mounting location (wall, ground, roof)

Mounting method (flat mounted, raised mounted)

Raised mounted considerations

- design data (wind and snow loads)
- roof repairs and or reinforcement
- expensive mounting frames bearing to walls or columns
- design of mounting frames and racks, roof penetrations

Pipe slope requirements

Component selection

- heat exchangers - size, type, costs
- piping - quantity, size, costs types, pipe connections, slopes required, heat transfer liquids, thermal expansion, valves, safety devices and control devises, hangers for pipes, aesthetics
- insulating materials - thickness, weatherproofing, fire rating

Control Systems

- protection provided
- simplicity
- reliability

Commissioning

- requirements
- commissioning documents

Operation Monitoring

- what is involved
- available documents

APPENDIX A

Product	Brand Name	Supplier
Insulation		
Glass Fiber	Micro-Lok 650	Johns-Manville
	Fiberglass ASJ	Fiberglass Canada
Urethane or Isocyanurate foam	Solar-7	Petro-Sun Inc. Montreal, Mississauga
Elastomeric	Armaflex	Armstrong
	Rubaflex	
Polyethelene	Therma-cell	Nomaco Inc.
Insulation Jackets		
Aluminum		General Aluminum Supply Corporation
Isogenepak, PVC	Montreal, Ottawa	Insul-Coustics
Insulation Jacket Accessories		
Aluminum or stainless steel strapping		Insul-Coustics Montreal, Ottawa
PVC Tape		Insul-Coustics Petro-Sun Inc.
Expansion Couplings		
Stainless Steel expansion bellows		Hydro Flex Inc. Hamilton
Flexible Hoses	EPDM	
	silicone	
Victaullic Couplings	Victaulic 75	Craine Canada Ltd.
	77	

Product	Brand Name	Supplier
Heat Exchanger Fluids		
Ethylene or Proplene glycol		Dow Chemicals Union Carbide Corp.
Heat Exchangers		
Tube in shell Plates		American Standard Alpha Laval Tranter Canada
Tube		Darling Duo.
Differential Controller		
Paget	CM 100	Paget Electronic Ltd Carleton Place, Ont.
Delta-T	DTT-400	Heliotrope General Spring Valley, Ca.
Independent Energy	C-30	Independent Energy Inc. East Greenway, RI
Solar Systems	DT-11H	Solarsystems Industries Ltd. Richmond, B.C.
Metal Support Systems		
Unistrut		GTE Unistrut

POOR

QUALITY

ORIGINAL